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Geotechnology applied in precision livestock farming

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ABSTRACT

The current state of animal production has faced several challenges, such as environmental, animal welfare and food safety. This has generated a new paradigm for the management and animal production. This article aims to review literature regarding livestock precision farming concepts, traceability and its history, traceability in Brazil, traceability of components, identification systems, geotechnology used in precision livestock. We can conclude that geotechnology can assist in herd management, animal performance in optimization of the use of pastures and preservation of natural and minimizing negative impacts resources. Thus, it contributes to the livestock industry can satisfy the food safety requirements, animal welfare and environmental sustainability.
Keywords: Geotechnology, precision livestock farming, traceability

INTRODUCTION

The comercial balance of Brazil, one of the main production sectors is agribusiness that has great potential for generating jobs, income and foreign exchange (RODRIGUES et al., 2008). Also within this segment, livestock production occupies one of the most significant, in particular the meat production sector. However, due to various health issues in recent years, especially with the mad cow disease (BSE - Bovine Spongiform Encephalopathy), together with increased consumer awareness, producers have solid required to provide greater transparency of their production systems (CÓCARO & JESUS SANTOS, 2007). Concomitant to this food safety problems, several studies have been developed to attach to livestock responsibility for various environmental problems such as emission of greenhouse gases by animals, changes in biogeochemical cycles and loss of local biodiversity.

Thus, the livestock precision farming has been developed to satisfy society demands, so it has been developed different tools and technologies, for example the implementation of traceability in animal production chains. This tool makes it possible to follow animals history throughout their production cycle and check various information, such as drugs, provided food, diseases, among others. This ensures greater security to consumers at the time of purchasing the product.

From this animal traceability systems infrastructure it is possible to support the producers with maximum information to perform decision-making and help the production unit management, so as to meet environmental and social demands. The various sectors of production have already incorporated in their activities technologies that assist in the production management, a key factor for an increasingly global market competition.

The primary sector does not escape this trend and, in the last 15 years there has been increasing use of computers and software to organize finances, keeping track of transactions and more effective production monitoring (KALOXYLOS et al., 2012). The agricultural sector needs to combine all collected data and make accurate decisions to produce quality, increasing profit and respecting government regulations. In addition to the information technology development, we had the great development geotechnology and it has revolutionized various sectors, especially the agricultural sector.

This article aims to review literature regarding livestock precision farming concepts, traceability and its history, traceability in Brazil, traceability of components, identification systems, geotechnology used in precision livestock.

REVIEW

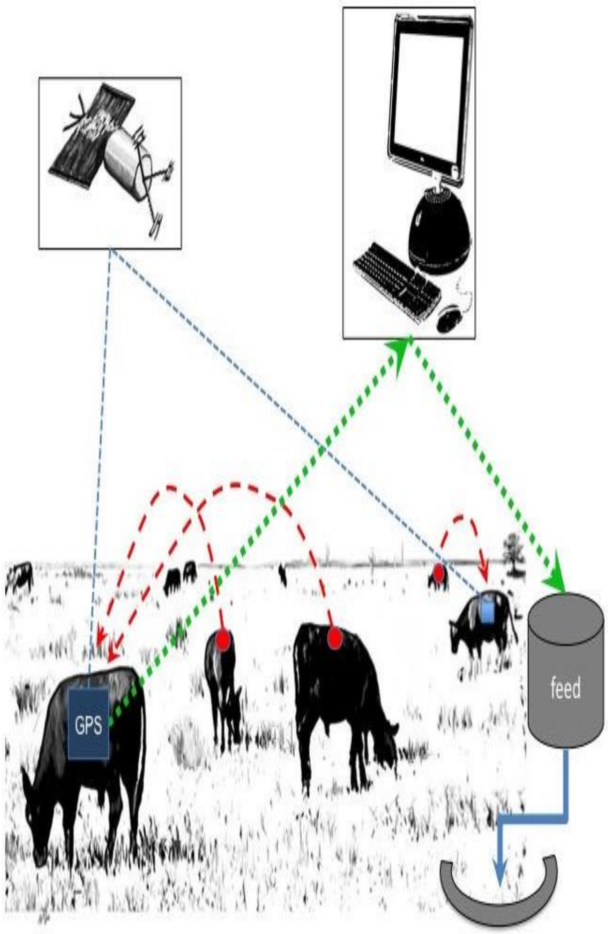
1. Precision Livestock Farmimg

The current state of animal production has faced several challenges, such as environmental, animal welfare and food safety. This has generated a new paradigm for the management and animal production. In this current design, producers can't concern only about of animal production, it is needed to integrate production to environmental services, enabling multifunctional habitats, and ensuring respect for animals and the food safety (CARVALHO et al., 2009).

Within this new context, the livestock precision farming has emerged and sought to meet all these prerogatives. According to Berckmans (2014) the livestock precision farming aims to create a management system based on automatic, real-time monitoring and control of production, reproduction, animal health, animal welfare and environmental impacts of livestock.

We have several technologies that can assist in the handling of animals, such as video cameras, microphones, sensors, GPS, wireless network, internet, among others. All of these technologies can be used to improve the efficiency of the production system and the adequacy to environmental requirements, animal welfare and food safety. Thus, the development of a precision livestock Farming system requires three fundamental steps: measuring, data analysis, and a control system (BANHAZI et al, 2012b.). With this precision livestock precision farming system will involve all components in the production and conduct a thorough analysis of a particular phenomenon of interest, as can be seen in Figure 1.

Figure 1 - Schematic model of precision livestock (LACA, 2009).



However, it is interesting to note that before the solidification of the concept of precision livestock farming, the traceability of animals was developed. This system sought to meet the specific problems like food safety, therefore, initially, traceability does not meet all the prerogatives precision livestock farming. The initial concern was limited to the movement control of animals and diseases (BANHAZI et al. 2012a).

With the progress in this area and new technologies, it was possible to realize that it is possible to integrate a traceability system to a precision livestock farming system. According to BANHAZI et al. (2012a) several benefits can be achieved with integration of traceability with precision farming, such as: producers can improve the animal feed and pasture, chain inputs providers can improve their products, slaughterhouses can choose animals and farms with animals with better conditions of weight and age for slaughter, among others.

So in the following subsections, we will see a little about the evolution of traceability and the technologies involved to better understanding how geotechnology can assist in precision livestock.

2. Evolution of Traceability in the food products chain

Food safety is a right guaranteed in various legal instruments, including being present in the Declaration of Human Rights, considered the right of every individual to have safe and sufficient food. Food safety is an issue that should be approached as a continuous result of a combination of research development with easy access to their results. This allows concluding that it is essential to control the food consumed. But there is no doubt that the triggering processes of increased concern about food safety were occurrences of mad cow disease (BSE - bovine spongiform encephalopathy) in Europe, FMD and, even today, of continuous scandals involving chemical residues and other banned substances (BLAHA, 2000).

In the twentieth century, with the so-called Green Revolution, a period of intense agricultural development around the world, it has the introduction of various chemical and physical resources to production control. It is evident with the advent of the green revolution, changes in the process of traditional agricultural management, as well as the impacts on the environment and human health (MOREIRA et al., 2002). Associated with this change in production, it has been changing the profile of consumers over time, which have become more demanding and critical.

According Beulens et al. (2005), concerns related to food safety has led companies to expand the offer of products and brands associated with quality and food safety; They demanded greater integration between chain elements such as government agencies and consumers with respect to food safety and quality in communication; recorded performance to support the requirements; and establish organizational and technical system to internal and external communication on its performance and ways to improve it (quality control system, tracking systems).

From the recent events, such as the legal requirements and food contamination on disputes, and the questions generated by mad cow disease and genetically modified foods, new concepts are being imposed in food production (MACHADO, 2005).

These changes resulted in the development of a new concept: traceability. Much wider than previously thought at first, it no longer applied from the industry (as was common) and went on to extend from the initial production processes of raw materials, primary producer, integrating it all production chain, also going to hold him accountable for the quality of the final food (CERUTTI, 2003).

Traceability is a concept originated from the desire of consumers to get more accurate information about the products consumed. The perception of consumers show a growing concern for the safety and properties of food consumed (BEULENS et al., 2005). Given these requirements, traceability has emerged as a method of food supply, uniting producers and consumers (REGATTIERI et al., 2007). According to Golan et al. (2004), the tracking system is based on the storage information to assess the flow characteristics of a product or of a product through the production process.

Vernède et al. (2003) state that traceability is the ability to track and / or locate the flow of a product in a chain of production and distribution, this implies a unique ID and allows some critical points to identity of the product is connected and the information systematically collected, processed and stored. The main objective of a traceability system is precisely determine the history and location of different products along the production chain (DABBENNE & GAY, 2011).

In an animal production system, the identification and registration of animals history are the basis for traceability of products of animal origin (CAPORALE et al., 2001). The animal identification can be performed individually or in homogeneous groups, depending on the purpose and used creation system (FALLON, 2001; MCKEAN, 2001). This is because certain farming systems perform the management of animals in lots or in groups, so the conditions are fairly uniform among animals.

Therefore, the food production industry realized that a transparent system of information of the entire supply chain would be necessary, so that consumer confidence was maintained. As a result, it was made improvements in communication schemes and processes that in order to be successful must ensure proper separation between the chain links through transparency, one of the requirements that ensures that the solutions are not isolated, being spread throughout the industry (LEHMANN et al., 2012).

Fisk & Chandran (1975) argue that traceability can be a mechanism to demonstrate that quality control is able to protect consumers before and after the sale of the products. It can also be a way to ensure the good faith of a company, ensuring the safety of their food to consumers. In addition, traceability can improve the understanding of the company on its distribution system, integrating the company to its customers.

A traceability when well established system can benefit other points that not only comes down on the food safety guarantee (ALFARO & RABADE, 2009). Although producers, particularly cattle, are getting price differentials by flocks with some sort of certification of origin, in other business traceability is only a competitiveness requirement without adding economic value.

Traceability scope depends on each industry and it is up to her to determine and specify their own objectives and methods. The implementation of a traceability system allows us to respond to food safety threats, simplify localization issues, reduce the volume of product returns, storing documentation of the production chain and production practices, ensure compliance with the regulation, establish responsibilities and analyze the costs and logistics (THARKUR et al., 2011; MACHADO, 2005) The sooner you identify and correct the cause of a deviation in the primary links, the smaller the losses and impacts.

Another important advantage of traceability is to demonstrate the company's performance, which can guarantee huge competitive improvement. Traceability facilitates the management to shares of the companies to identify critical situations, causes and withdrawal of defective parts or inadequate processes (BRIZ & FELIPE, 2004).

Therefore, the correct storage of information will compare which actions were effective and which require adjustments, such as weight gain, feed intake, feed conversion, health aspects, reproduction, influence of management and the physical environment in animal performance. As well say Machado & Nantes (2004), regardless of market demand, the producer will need to collect, process and control information of your property in order to organize and plan their activities.

It should be noted that in a situation of contamination or diseases in animals, an adequate traceability system will facilitate the identification and call of the contaminated products, saving costs and reduce damage to the company's image The studies developed by Kumar & Budin (2006) and Randrup et al. (2008) sought to model and predict the effects of products call (recall) while Dabbene & Gay (2011) sought to develop an optimization model products call costs.

3. Traceability in Brazil

Traceability in Brazil emerged from a strong pressure from the European Union (RODRIGUES & NANTES, 2010), particularly in Beef Cattle This is because of cases of mad cow and FMD and cause great distrust of international consumers (FERRAZZA et al., 2013). Because of these occurrences, the Ministry of Agriculture created the Brazilian System of Identification and Certification of Bovine and buffalo (SISBOV) program, which began tracking the Brazilian cattle herd. However, in other animal production chains, the registration system is still very incipient forward to the adoption of a traceability program for the sectors.

The minimum identification a meat product must contain to be exported, is the country to origin of the product, slaughter establishment, product brand name and product code, production date and / or expiration, and other information additional such as lot code and seal, etc. In possession of the product identification it is possible to reconstruct all the information relating to products, such as origin of the material used and its characteristics (MACHADO, 2005).

4. Components Traceability

There are two types of traceability: internal and external. The Internal traceability checks the actions within the company while the external traceability follows the actions throughout all stages of products and inputs. So to be done properly the traceability of products throughout the supply chain, it is necessary some basic elements: identification of properties, The animal identification and storage activities.

The identification of the properties is the basis to find more information about the animals, which will determine areas of contamination or disease control, in addition to providing information to consumers (Smith et al., 2011) This ensures greater transparency of the company, as in the current context of the global market is an important tool for organizations' competition.

Order to implement an animal traceability system and its products, it is necessary to identify the basic elements (OLIVARES, 2011), such as identification devices, activity logs, database, activities validation system (certification).

For identification of incoming goods, whether raw materials, supplies, packaging and others, are given by the labeling of fractionated products and records for bulk products. According to production units characteristics, identification of animals can be given individually. The product manufacturing process is the identification given batch of product and or records.

According to Cerutti (2003), finished products and commercialization have their identification given through labeling on the product, minipallet and or container, all connected with records that provide traceability, traceable product quality and performance in the production process at different stages industrial and agricultural production.

To control and registration, of their birth until the time of slaughter, it is need to keep updated records on the movement of the herd, calving records and coatings and drug usage records.

The database aims to store all information pertaining to activities in the sectors It is important to note that the main objectives for a database, according to Olivares (2011) is keeping an updated record of the animals, owners and other components, to emit report on animal movements and on the health of the herd situation.

The validation system (certification) is the way that ensures the product according to the given specifications, so include sampling, testing, assessment and assurance of conformity (MACHADO, 2005) Thus, to ensure credibility, it must be carried out by independent organizations and without any relationship with the organization in the certification process.

A really effective traceability must integrate all the components involved in the production cycle making use of standardized measurement procedures, analysis, storage and transmission of the information collected in order to evaluate the entire history of the product. Opara (2003) points out that an integrated traceability system is based on collection of information and computer systems technologies, connecting the company's database with government institutions both national and international, composed of different elements that formed the program traceability (Figure 2).

Figure 2. Description of the elements forming the traceability program Adapted from Opara (2003).

For traceability function properly, the animals need to be identified individually. Lirani (2008) states that even for the full cycle of producers in the raising, breeding, fattening and sale for slaughter are made by the same producer, if there is no individual identification of animals, there is the possibility of loss of traceability. With the identification must be coupled identification code ensuring the identity of the animal (OLIVARES, 2011).

Importantly for food and storage of information on traceability, the electronic form is the most safe and feasible, as it enables faster and more efficient exchange between businesses. However, the establishment of a globally accepted language is an important problem to be considered. Therefore, an assembly for a basic model it is necessary to allow to be applied in different productive realities associated with the determination of the important information to be recorded by producers (SMITH et al., 2011).

However, traceability is not just the identification of animals, it is necessary to evaluate and store information throughout all stages of the production chain. Machado (2000) states that the traceability concept is associated with the identification of the product at various stages for the production cycle, in which each one is read some information, is related to the location, action or intrinsic characteristics, requiring store data collected so that it can be offered throughout the stages (OLIVARES, 2011).

Therefore, the main objectives database traceability for animals are: keeping records for all activities performed in animals, herds, owners and responsible to inform all movements made by the animals, report on the health status of animals and provide different information for the government and consumers.

Traceability for small and medium producers is a major challenge, as the greatest obstacle is precisely represented by the costs necessary for the implementation of traceability program and its maintenance. Therefore, the use of appropriate technologies to the reality of the producers is an essential factor for a satisfying and successful traceability.

5. Animal Identification Systems

There are several forms of animal identification, which can be classified among systems that use an external form and those who use natural features of the animals. Some examples, they have: earrings, tattoos, microchips, collars, retinal analysis or DNA (Smith et al., 2011).

The system that uses earrings allows it to be used in large herds, presenting different options, such as different colors, bar code, format, and numbering. Marsão & Gonçalves (2008) state that it is necessary to take some precautions in time of application, because, it may cause injury to the animal. It can be coupled with a numbering, barcode or microchip.

According to these authors, the collars with identification system works similar to earrings, but their application are easier and do not hurt the animal. However, one should be aware of the material that will be done, so it is not very brittle and break, hampering identification.

The method for tattoos can be very effective in identifying, if it is done with proper care, being used with a number or mark owned However, they have the disadvantage of difficult to read, hampering agility management, since the animal must be restrained so that the reading for identification is made (SCHMIDEK et al., 2009).

In iron marking system, there are two types: cold and hot. To ensure the quality of marking and prevent injury, the animal should be well fixed cold brand facilitates animal viewing with the dark While the brand hot, difficult to display in lanados animals or the dark (MARSÃO & GONÇALVES, 2008). It can be used to identify the breed, the owner, the individual and also the realization of certain management practices.

Electronic ID system ensures agility in identifying and reading and is also known as RFID (Radio Frequency Identification Devices). It is an extremely safe and agile system, according to Machado & Nantes (2004), its implementation is focused to improving the quality, economy and / or environmental impact of animal production.

The interest occurred in this identification method from the desire to use a method that facilitates tracking and were used globally (FELMER et al., 2006) According to Ruiz-Garcia & Lunadei (2011), this method has a number of advantages over the other methods of identification, such as: does not require a direct contact of the handler with the equipment; It can be coupled to other objects or inside the animal; and much higher reading speed.

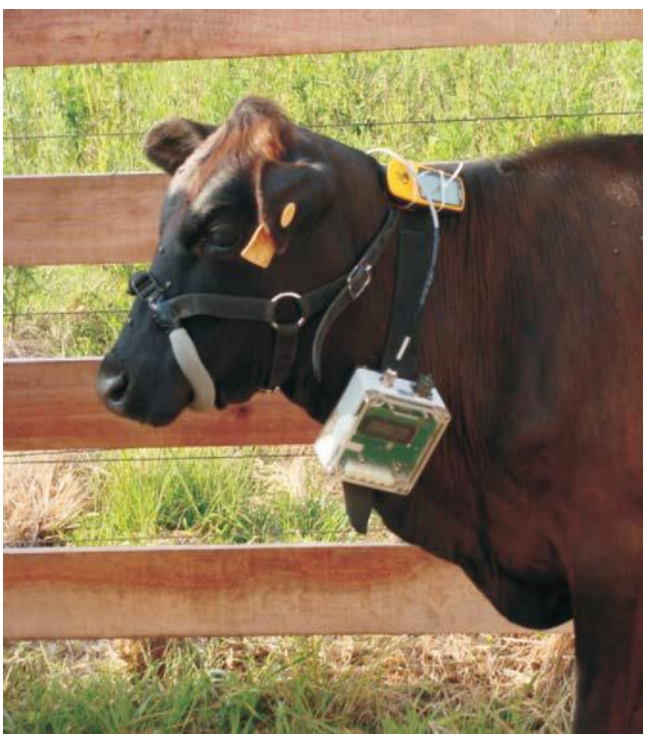
With the three types of electronic identifiers on the market: the external earring, or necklace, wrapped in a sealed plastic capsule with the microchip; injection under the skin of the animal and another pill to be offered as contained in the rumen of the animal cake (MACHADO, 2000).

These devices are capable of storing and transmitting information or code, serving to identify the individual animal. The principle for operation of this identification method is based on an antenna, responsible for making the reading of the microchip, which creates an electromagnetic field, which is used by the transponder to generate the proper activation energy in this way sends a signal that returns to transceiver (ARTMANN, 1999).

Regarding these electronic identifiers, we have two types: passive and active. Passive sensors do not have their own power for its operation, therefore, the sensor only reacts when exposed to some mechanism that generates electromagnetic energy, such as reading antennas. Active sensors have their own power and are active during the lifetime of the battery, in addition, this type of sensor makes it possible to perform reading at greater distances and collect and store data on microchip (GOMES, 2010) Thus, it is possible to connect to devices that enable to determine the behavior for the animal or read the geolocation through a GPS.

This technology has been applied for a long time in the Wildlife animal with GPS technology which allows checking the movements of animals. In livestock production, some other initiatives have been undertaken to obtain an identification sensor coupled with a GPS sensor. Current technologies allow measuring the position of animals with an accuracy of 10 m (LACA, 2009), as it is possible to see in figure 3.

Figure 3. Heifer with IGER Behaviour Recorder and GPS (GENRO & NABINGER, 2009).



In Brazil, there is the OTAG project that foresees the use of electronic devices for georeferencing in animals beef cattle chain, as well as the acquisition, storage and analysis of drive data (BRAGANTINI, 2011). So each animal uses an electronic collar, which determines and stores at a given frequency to its position. Electronic Collars to Track Cattle (ECTC) is a necklace of ID that has a GPS sensor developed on OTAG project, this information is used in the information system developed by the project, according to the developed structure.

The system created allows collars send information periodically to the base station that stores all the data of all animals. In addition to the identification of the animal's identification number and your geolocation, collars developed in this system can collect other data, such as temperature and weight others devices on the property.

This system has some operational difficulties and because of that other initiatives were developed. Jesus (2014) created a sensor node that can obtain monitoring data from animals and infer their behavior through a collection system with wireless network. This device developed also has a GPS sensor that collects the animal's position periodically and stores the collected data in a memory card which are then discharged into an information system.

Therefore, these devices enable uniquely identify an animal track all actions done and provide a history of each, basic requirements traceability. Just as it can obtain data from geolocation history and monitor grazing patterns and associate the behavior of animals, paving the way for better management of natural resources.

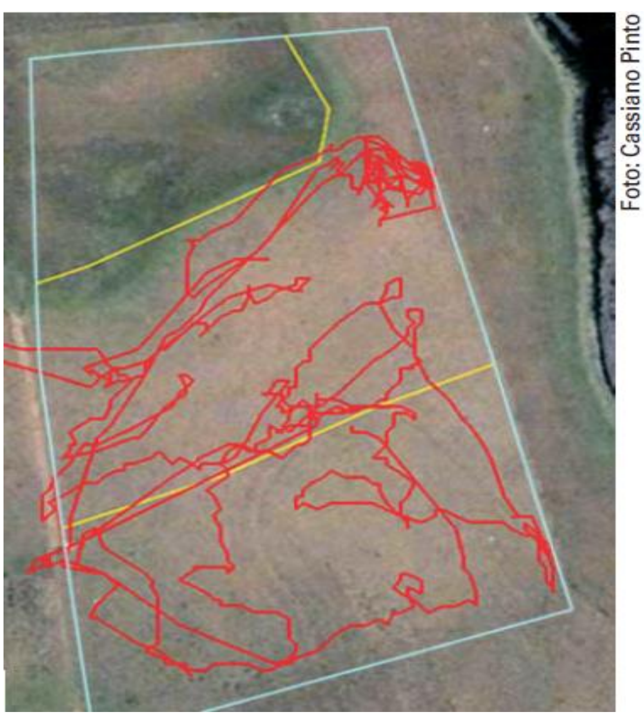
6. Geotechnologies applied in Precision Livestock Farming

The livestock activities produce strong effects on the natural environment in various ways, so it is necessary to use techniques to suit the requirements and environmental standards, as well as food safety and welfare of animals. Adler et al. (2001) states that grazing can alter the biodiversity and spatial heterogeneity for some attributes Thus, one can infer that the spatial structure of an ecosystem can be altered by grazing conditions.

Understanding the factors that influence the spatial behavior of animals is essential to understand how environmental impacts occur and enable use more efficient natural resources. Several factors contribute to animal movement pattern, for example the availability of food, water, nutrients, shadows and other factors (RUTTER, 2007).

Thus, the geotechnology can be an important tool that helps to better understand the patterns of consumption and movement of animals, such as impacts on the environment in livestock are generated and to determine mitigation activities. These technologies make it possible to collect, store, process and present spatial information (Figure 4).

Figure 4. Representation of the animal grazing trajectory (red line), obtained by integralization data from IGER equipment and GPS, UFRGS, January 2009 (GENRO & NABINGER, 2009).



Páscoa & Costa (2007) developed some studies with GIS use in evaluating spatial behavior of cattle. One activity evaluated the grazing time in some areas of pasture based on the physicochemical characteristics of forage, using a multivariate correlation in GIS environment based on the spatial distribution of variables. Moreover, they have also developed a study featuring use of space pattern, by means of a dispersion map feces in a pasture area, by means of geostatistics.

A program that is under development is Observing System and Monitoring of Agriculture in Brazil (SOMABRASIL). This project aims to develop the chain cattle a system based on geotechnology and collaborate to determine the positioning of cattle (ANDRADE et al., 2015). Thus it has been possible to verify the preferences of grazing animals and patterns and outcomes have been considered very promising in determining the behavior of the animals and environmental interactions in conjunction with mobility.

Another study developed by Long et al. (2010) have used images of Terra MODIS (MODIS) and geospatial data to estimate productivity of pastures and sheep carrying capacity on a farm in China. The authors observed the integration of remote sensing with geotechnology can assist in decision making animal production properties and evaluate the spatial and temporal distribution of pasture conditions.

It is possible to observe that geotechnology can assist in identifying grazing patterns and assist in its modification.

In addition to assisting in the animals history grazing, geotechnologies can also help producers in the construction of the farm structures. In a study conducted by Sliz-Szkliniarz & Vogt (2012), they integrated spatial and non-spatial data in Geographic Information System to help determine the best locations for installation for anaerobic digesters on a livestock farming, which obtained satisfactory results.

It is important to emphasize that the latest technologies such as drones, have helped significantly and enhancing the geotechnology in the agricultural sector However, given the fact that its use in Brazil is so recent, still need further studies on the subject and propose methods for use of these technologies There is also lack of studies with use of geotechnology in regions for the Brazilian semiarid region In turn, the development of studies and extent of this area of knowledge to region may represent a major advance, since this area has a strong ability for livestock activities, in particular for sheep and goat production.

In conclusion, there is no doubt that the geotechnology can assist in herd management, animal performance in optimization of the use of pastures and preservation of natural and minimizing negative impacts resources. Thus, it contributes to the livestock industry can satisfy the food safety requirements, animal welfare and environmental sustainability.

REFERENCES

ADLER, P.B.; RAFF, D.A.; LAUENROTH, W.K. The effect of grazing on the spatial heterogeneity of vegetation. *Oecologia*, v.128, p.465-479, 2001.

ALFARO, J.A.; RÁBADE, L.A. Traceability as a strategic tool to improve inventory management: A case study in the food industry. *International Journal Production Economics*, v. 118, n. 1 p. 104–110, 2009.

ANDRADE, R. G.;, BOLFE, É. L.; BATISTELLA, M. Georrastreabilidade. Sustentabilidade da bovinocultura. *AgroANALYSIS*, v. 35, n. 1, p. 29-31, 2015.

ARTMANN, R. Electronic identification systems: state of the art and their further development. *Computers and Electronics in Agriculture*, v. 24, n. 1, p. 5-26, 1999.

BANHAZI, T. M., LEHR, H., BLACK, J. L., CRABTREE, H., SCHOFIELD, P., TSCHARKE, M.; BERCKMANS, D. Precision livestock farming: An international review of scientific and commercial aspects. *International Journal of Agricultural and Biological Engineering*, v. 5, n. 3, p. 1-9, 2012.

BANHAZI, T. M.; BABINSZKY, L.; HALAS, V.; TSCHARKE, M. Precision Livestock Farming: Precision feeding technologies and sustainable livestock production. *International Journal of Agricultural and Biological Engineering*, v. 5, n. 4, p. 54-61, 2012.

BERCKMANS, D. Precision livestock farming technologies for welfare management in intensive livestock systems. *Rev. sci. tech. Off. int. Epiz*, v. 33, n. 1, p. 189-196, 2014.

BEULENS, A.J.M.; BROENS, D.F.; FOLSTAR, P.; HOFSTEDE, G.J. Food safety and transparency in food chains and networks relationships and challenges. *Food Control*, v. 16, p. 481–486, 2005.

BLAHA, T. G. Manejo de qualidade na granja, segurança alimentar pré-abate e certificação da indústria suinícola. *In: Conferência Internacional Virtual sobre Qualidade de Carne Suína*, p.1-16, 2000, Concórdia. Anais... Concórdia: Embrapa Suínos e Aves. Disponível em: <http://www.cnpsa.embrapa.br/pork/anais00cv_blaha_pt.pdf>. Acesso em: 11 de Janeiro de 2014.

BRAGANTINI, C. A transferência de tecnologia na Embrapa: uma analise e propostas de mudanças conceituais e metodológicas com ênfase em geotecnologias. *Cadernos de Ciência & Tecnologia*, v. 28, n. 2, p. 533-575, 2011.

BRIZ, I.F.J.; DE FELIPE, I. *Seguridad alimentaria y trazabilidad*. Universidad Politécnica de Madrid: ETSIA Madrid, 2004.

CARVALHO, P. C. D. F.; TRINDADE, J. K. D.; MEZZALIRA, J. C.; POLI, C. H. E. C.; NABINGER, C., GENRO, T. C. M.; GONDA, H. L. Do bocado ao pastoreio de precisão: compreendendo a interface planta-animal para explorar a multi-funcionalidade das pastagens. *Revista brasileira de zootecnia*, vol. 38, supl. especial, p. 109-122, 2009.

CAPORALE, V., GIOVANNINI, A., DI FRANCESCO, C., CALISTRI, P. Importance of the traceability of animals and animal products in epidemiology. *Revue Scientifique et Technique - Office International des Epizooties*, v. 20, n. 2, p. 372–378, 2001

CERUTTI, M. Implantação de programa de rastreabilidade da indústria avícola. *In: Seminário Internacional sobre Qualidade de Aves–Avesui*, 2003. Disponível em: <http://www.avisite.com.br/cet/4/04/index2.sthm>. Acesso em: 03 de Fevereiro de 2014.

CÓCARO, H.;& SANTOS JESUS, J.C. Impacts of bovine traceability implantation in computerized rural companies: case studies. *Journal of Information Systems & Technology Management*, vol.4, n.3, p. 353-374, 2007.

DABBENNE, F; GAY, P. Food traceability systems: Performance evaluation and optimization. *Computers and Electronics in Agriculture*, v. 75, n. 1, p.139–146, 2011.

FALLON, M. Traceability of poultry and poultry products. *Revue scientifique et technique (International Office of Epizootics)*, v. 20, n. 2, p. 538-546, 2001.

FELMER, R.; CHAVEZ, R.; CATRILEO, A.; ROJAS, C. Tecnologías actuales y emergentes para la identificación animal y su aplicación en la trazabilidad animal. *Archivos de medicina veterinária*, v.38, n. 3, p. 197-206, 2006.

FERRAZZA, R.A.; SCHULLER, M.C.; LOPES, M.A.; LAGE, L.A. Rastreabilidade bovina na região Centro-Sul do estado de Mato Grosso: aspectos econômicos, técnicos e conceituais. *Boletim de Indústria Animal*, v. 70, n. 2, p. 110-118, 2013.

FISK, G., CHANDRAN, R. Tracing and recalling products. *Harvard Business Review*, p. 90–96, 1975.

GENRO, T.C.M.; NABINGER, C. *Considerações para o uso sustentável da pastagem natural com diferentes intensidades de uso*. Bagé: Embrapa Pecuária Sul, 2009. (Documento, 95).

GOLAN, E.; KRISSOFF, B.; KUCHLER, F. Food traceability: one ingredient in a safe and efficient food supply. *Economic research service*, v. 2, p.14–21, 2004.

GOMES, L.C. *Identificação por rádio frequencia (rfid) aplicado ao rastreio de bovinos*. 2010.50 f. Monografia (Graduação em Ciências da Computação) – Universidade Federal do Mato Grosso, Cuiabá, 2010.

JESUS, L. *Identificação do comportamento bovino por meio do monitoramento animal*. 2014.106 f. Dissertação (Mestrado em Ciências da Computação) – Universidade Federal do Mato Grosso do Sul, Campo Grande, 2014.

KALOXYLOS, A.; EIGENMANN, R.; TEYE, F.; POLITOPOULOU, Z.; WOLFERT, S.; SHRANK, C.; DILLINGER, M.; LAMPROPOULOU, I.; ANTONIOU, E.; PESONEN, L.; NICOLE, H.; THOMAS, F.;

ALONISTIOTI, N.; KORMENTZAS, G. Farm management systems and the Future Internet era. *Computers and Electronics in Agriculture*, v. 89, p.130-144, 2012.

KUMAR, S., BUDIN, E., 2006. Prevention and management of product recalls in the processed food industry: a case study based on an exporter's perspective. *Technovation*, v. 26, n. 5, p. 739-750, 2006.

LACA, Emilio A. Precision livestock production: tools and concepts. *Revista brasileira de zootecnia*, v.38, n. especial, p.123-132, 2009.

LEHMANN, R.J.; REICHE, R.; SCHIEFER, G. Future internet and the agri-food sector: State-of-the-art in literature and research. *Computers and Electronics in Agriculture*, v. 89, p. 158-174, 2012.

LIRANI, A.C. Rastreabilidade na cadeia produtiva das carnes caprinas e ovinas. *Tecnologia & Ciências Agropecuárias*, v.2, n.3, p.71-79, 2008.

LONG, Y. U., LI, Z. H. O. U., WEI, L. I. U., & HUA-KUN, Z. H. O. U. Using remote sensing and GIS technologies to estimate grass yield and livestock carrying capacity of alpine grasslands in Golog Prefecture, China. *Pedosphere*, v. 20, n. 3, p. 342-351, 2010.

MACHADO, J.G.C.F.; NANTES, J.F.D. A rastreabilidade na cadeia bovina. In: *1º CONGRESSO LUSO-BRASILEIRO DE TECNOLOGIAS DE INFORMAÇÃO E COMUNICAÇÃO NA AGRO-PECUÁRIA*, 2004, Santarém. Tópicos...Santarém: Associação Portuguesa para o Desenvolvimento das Tecnologias de Informação e Comunicação na Agricultura.

MACHADO, R.T.M. *Rastreabilidade, tecnologia da informação e coordenação de sistemas agroindustriais.* 2000. 239 f. Tese (Doutorado em administração) - Universidade de São Paulo. São Paulo: USP

MACHADO, R.T.M. Sinais de qualidade e rastreabilidade de alimentos: uma visão sistêmica. *Organizações Rurais & Agroindustriais*, v. 7, n. 2, p. 227-237, 2005.

MARSÃO, D.J.M; GONCALVES, A.C. *Sistemas de identificação de ovinos*. Farmpoint, São Paulo, 17 de julho de 2008. Disponível em: <http://www.farmpoint.com.br/radares-tecnicos/sistemas-de-producao/sistemas-de-identificacao-de-ovinos-46482n.aspx>. Acessado em: 29 de Março de 2013.

MCKEAN, J.D. The importance of traceability for public health and consumer protection. *Revue scientifique et technique (International Office of Epizootics)*, v. 20, n. 2, p. 363, 2001.

MOREIRA, J. C., JACOB, S. C., PERES, F. Avaliação integrada do impacto do uso de agrotóxicos sobre a saúde humana em uma comunidade agrícola de Nova Friburgo, RJ. *Ciência e Saúde Coletiva*, v. 7, n. 2, 2002.

OLIVARES, M.A.R. *Trazabilidad de Ganado ovino mediante el uso de marcadores biométricos y electrónicos.* 2011. 113 p. Tese – Universitat Autònoma de Barcelona, Barcelona.

OPARA, L. U. Traceability in agriculture and food supply chain: A review of basic concepts, technological implications, and future prospects. *Food, Agriculture & Environment*, v.1, p. 101-106, 2003.

PÁSCOA, A.G.; COSTA, M. J. R. P. Aplicação dos sistemas de informação geográfica para definição de estratégias de manejo de bovinos nas pastagens. *Revista Brasileira de Zootecnia*, v. 36, p. 45-51, 2007.

RANDRUP, M., STORØY, J., LIEVONEN, S., MARGEIRSSON, S., ARNASON, S.V., OLAVSSTOVU, D., MØLLER, S.F., FREDERIKSEN, M.T. Simulated recalls of fish products in five Nordic countries. *Food Control*, v. 19, n. 11, p. 1064–1069, 2008.

REGATTIERI, A.; GAMBERI, M.; MANZINI, R. Traceability of food products: General framework and experimental evidence. *Journal of Food Engineering*, v. 81, n. 2, p. 347-356, 2007.

RODRIGUES, G.Z.; GOMES, M.F.M; CUNHA, D.A; SANTOS, V.F. Evolução da produção da carne suína no Brasil – uma análise estrutural-diferencial. *Revista de economia e agronegócio*, v. 6, n. 3, 2008.

RODRIGUES, L.C.; NANTES, J.F.D. Rastreabilidade na cadeia produtiva da carne bovina: situação atual, dificuldades e perspectivas para o Brasil. *Informações Econômicas*, v. 40, n. 6, p.31-41, 2010.

RUIZ-GARCIA, L; LUNADEI, L. The role of RFID in agriculture: Applications, limitations and challenges. *Computers and Electronics in Agriculture*, v. 79, n.1, p. 42-50, 2011.

RUTTER, S.M. The integration of GPS, vegetation mapping and GIS in ecological and behavioural studies. *Revista Brasileira de Zootecnia*, v. 36, p. 63-70, 2007.

SCHMIDEK, A; DURÁN, H; M.J.R, PARANHOS DA COSTA. Boas Práticas de Manejo, Identificação. Jaboticabal: Funep, 2009.

SLIZ-SZKLINIARZ, B.; VOGT, J. A GIS-based approach for evaluating the potential of biogas production from livestock manure and crops at a regional scale: A case study for the Kujawsko-Pomorskie Voivodeship. *Renewable and Sustainable Energy Reviews*, v. 16, n. 1, p. 752-763, 2012.

SMITH, I.G (ed). *Acceptable and Practical Precision Livestock Farming for SMEs in Europe and Worldwide.* United Kingdom: Bright Animal - EU Framework 7 Project, 2011. 207p.

THARKUR, M.; MARTENS, B.; HURBURGH, C.R. Data modeling to facilitate internal traceability at a grain elevator. *Computers and Electronics in Agriculture*, v. 75, p.327–336, 2011.

VERNEDE, R., VERDENIUS, F., AND BROEZE, J. Traceability in food Processing Chains: State of the Art and Future Developments. *Agrotechnology and Food Innovations*, 2003.

VOULODIMOS, A.S.; PATRIKAKIS, C.Z.; SIDERIDIS, A.B.; NTAFIS, V.A.; XYLOURI, E.M. A complete farm management system based on animal identification using RFID technology. *Computers and Electronics in Agriculture*, v. 70, n. 2, p.380-388, 2010.